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EARLY AUTUMN MOVEMENTS AND DENSITIES OF JOHNNY (*ETHEOSTOMA NIGRUM*) AND FANTAIL (*E. FLABELLARE*) DARTERS IN A SOUTHWESTERN OHIO STREAM[1]

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ABSTRACT. Early autumn movements of johnny (*Etheostoma nigrum*) and fantail (*E. flabellare*) darters were examined in a pool-riffle system. Of the 340 johnny darters marked during the study, only 3.24% (10) of recaptured fish (N = 309) moved. Three hundred and forty-one fantail darters were marked, and 12.78% (17) of recaptured fish (N = 133) moved. Over 75% of all movements were in an upstream direction. Chi-square analyses indicated that movements were restricted to areas near the point of initial capture. Density estimates of the pool-dwelling johnny darter ($0.80/m^2$) were lower than those of the riffle-dwelling fantail darter ($5.59/m^2$). These results suggest that population density and habitat quality may influence the seasonal movements of stream fishes.

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INTRODUCTION

Some stream fish are known to spend much of their lives in very restricted habitats. Gerking (1953) found that 5 centrarchid species confined their movements to small areas of stream for up to a 4-year period. Similar results were reported for several salmonid species (Stefanich 1952, Mense 1975, Cargill 1980, Leclerc and Power 1980). While at least some darters (Pisces: Percidae) are migratory preceding and following spawning periods, they are apparently sedentary during other, non-reproductive periods (Winn 1958). Reed (1968) studied 8 species of darters that inhabit riffles during the summer and found that only 2.4% of recaptured, marked individuals (N = 2269) moved to adjacent riffles. A study of the orangebelly darter (*Etheostoma radiosum cyanorum*) revealed no inter-raceway movements during the spring and summer (Scalet 1973). However, intra-raceway movements of less than 30 m were observed during the same period. Darter movements during the autumn months have not been systematically examined.

The present study was designed to determine the degree and direction of early autumn movements by populations of johnny (*Etheostoma nigrum*) and fantail (*E. flabellare*) darters inhabiting adjoining pool and riffle habitats, respectively. Estimates of darter population densities in the pool-riffle system were also made.

STUDY SITE

Harker's Run, a tributary of Four Mile Creek in Butler County, Ohio, was chosen as the study area. Preliminary seining indicated that in addition to johnny and fantail darters this stream also contained the banded (*Etheostoma zonale*) and rainbow (*E. caeruleum*) darters, though in much lower numbers. Other common species included the silverjaw minnow (*Ericymba buccata*), common stoneroller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys atratulus*), and northern hog sucker (*Hypentelium nigricans*).

Harker's Run is typical of well-oxygenated, hardwater streams in southwestern Ohio. During the study period

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(12 September–14 October 1980) dissolved oxygen averaged 11.0 mg/L, while total hardness and alkalinity averaged 327.5 and 267.5 mg/L as $CaCO_3$, respectively. Conductivity ranged from 235 to 300 μmhos/cm, and pH remained constant at 8.1. Stream temperature declined gradually from 20 C on 12 September to 12 C on 14 October.

A 187.3-m section of stream was selected for study. This section contains 4 riffles that are separated by 3 pools. Total surface areas for the pools and riffles were 505 and 112 m^2, respectively. Each pool and riffle possessed a combination of physical conditions which made it distinct from the other areas. Substratum in pools consisted mainly of silt, sand, and gravel, while in the riffles cobbles and flat rocks ($\leq$20 cm diam.) were prevalent. Pool and riffle depths ranged from 9–29 and 5–6 cm, respectively. Mean current velocities (Gurley Model 625 pygmy current meter) in the riffles ranged from 30–45 cm/sec; current in the pools was negligible.

METHODS AND MATERIALS

Darters were captured with a 1.22 × 3.66 m seine (mesh size = 6.35 mm). Pools were seined a total of 3 times on each sampling date. Scalet's (1973) sampling technique was used in the riffles. The seine was set across the stream at the foot of each riffle, and the substrata upstream from the net were kicked vigorously to drive darters downstream into the seine. This process was repeated until all areas of each riffle had been disturbed 5 times on each date. Longer riffles were divided into shorter sections to enable more efficient sampling.

Initial sampling of johnny and fantail darters was carried out on 12 September. Darters were given characteristic fin-clips with small scissors to designate the pool or riffle in which they were originally captured. Portions of the right or left pectoral or pelvic fin, the soft dorsal fin, or the top or bottom corner of the caudal fin were removed. Seining was begun at the downstream riffle and then continued in an upstream direction to minimize recapture of newly-marked fish. Reed (1968) found that marked darters retreated downstream temporarily after fin-clipping. This was apparently a behavioral pattern resulting from shock.

Effects of fin clips on johnny and fantail darters were evaluated in the laboratory by observing marked fish (N = 30) placed in a 492-L Living Stream (Frigid Units, Inc.). The fish that were used in this experiment were collected downstream from the study area. No adverse effects on behavior or survival of marked individuals were detected over a 70-day period.

In the period (13 September–14 October) following initial marking, the study area was seined on 7 occasions. On each date, captured darters were examined for the presence of clipped fins. Marked fish were recorded as recaptures, and fish not marked received the area-specific fin clips. Ages of the fish were not determined. All captured fish were returned to the middle of the area from which they were collected. The study period was terminated on 14 October, when leaves filled the stream and prevented further seining.

The results on movements of the 2 darter species were analyzed with Chi-square goodness of fit tests by assuming that darters showed no affinity for the area where they were originally marked. Thus, the distribution of fish recaptured outside the area of original capture should be proportional to the number of fish recaptured in each of the various areas (Mense 1975). Such tests help to determine if movement patterns are random, or if they are oriented around the area of initial capture. This method was used by Gerking (1953) and Mense (1975) to examine within-stream movements of rock bass (*Ambloplites rupestris*) and brown trout (*Salmo trutta*), respectively.

The density of each darter species in the entire study area and in each of the riffles and pools was calculated with the Schnabel method (Ricker 1975). The equation is:

$$N = \frac{\Sigma MC}{\Sigma R},$$

where N is the population estimate, M is the number of marked fish available for recapture, C is the number of fish captured, and R is the number of marked recaptures.

RESULTS

Three hundred and forty johnny (*E. nigrum*) and 341 fantail (*E. flabellare*) darters were marked and released in the study area. A total of 309 johnny darters was recaptured; of these, 10 (3.24%) displayed movement from the area of original capture to another riffle or pool. The corresponding values for the fantail darter were 133 and 17 (12.78%). Individual movements of both species are summarized in table 1. Over 75% (21 fish) of all movements were upstream. Average distance travelled (*E. nigrum*: 55 m; *E. flabellare*: 62 m) was similar for both species, with 80% (22 fish) of all movements covering a minimum of 36 m. Also, 80% of all darters that moved were recaptured no further than 2 stream areas distant from the point of initial capture (table 1).

Observed and expected frequencies of recapture of johnny and fantail darters were calculated for each of the 7 areas in the study section. As a large number of the expected values were less than 1, the data were pooled before the Chi-square analyses were performed (Cochran 1952). Data were combined on all fish that showed no movement, that moved from one area to an adjacent area, that moved 2 areas away, and so on. The results of these analyses are given in table 2. When Chi-square tests were applied to the data, highly significant values were obtained (table 2). Hence, the observed autumn movements of johnny and fantail darters in the stream were not random, but were restricted to areas near the point of initial capture.

Using the Schnabel formula, it was estimated that 401 johnny and 632 fantail darters inhabited the study area. Johnny darters were found almost exclusively in pools, and fantail darters were rarely located away from the riffles. There were 0.80 johnny darters/m^2 of pool and 5.59 fantail darters/m^2 of riffle in the study area.

The population estimates and densities of johnny and fantail darters for each pool and riffle are summarized in table 3. Fish which exhibited movement between the various locations in the study area were not included in these calculations because the Schnabel formula is based on the assumption that no immigration or emigration occurs. The data indicate that darter densities in the 4 pools (*E. nigrum*: 0.53–1.26/m^2) were lower than in the riffles (*E. flabellare:* 1.88–20.50/m^2).

DISCUSSION

The results of this study indicate that johnny darters move very little in Harker's Run during early autumn. This low degree of movement by the johnny darter during the non-reproductive period is similar to that observed for other stream fishes (Stefanich 1952, Gerking 1953, Mense 1975, Cargill 1980, Leclerc and Power 1980), and for darters that inhabit riffles (Reed 1968, Scalet 1973). Fantail darters displayed more movement, however, than has been reported previously for darters

TABLE 1

Movements of johnny (E. nigrum) *and fantail* (E. flabellare) *darters in Harker's Run, Ohio, as determined by mark-and-recapture experiments.*

	Movement		Distance (m)	
Species	Upstream	Downstream	Minimum	Maximum
E. nigrum	1 (R1 to P1)*		13.8	46.3
		1 (R2 to P1)	10.0	42.5
	7 (P1 to P2)		36.3	79.3
	1 (R1 to P2)		66.3	109.3
E. flabellare	1 (R1 to P1)		13.8	46.3
	1 (R1 to R2)		46.3	66.3
		1 (R2 to R1)	52.2	60.3
		1 (R4 to R1)	177.0	185.1
	1 (R2 to R4)		122.7	127.0
		2 (R4 to R2)	114.8	134.8
	8 (R3 to R4)		36.0	40.3
		1 (R4 to R3)	34.2	41.9
	1 (P3 to R4)		16.1	20.4

*R = Riffle (1, 2, 3, or 4); P = Pool (1, 2, or 3).

TABLE 2

Pooled observed and expected recapture frequencies and Chi-square analyses of johnny (E. nigrum) *and fantail* (E. flabellare) *darter movements. Fish recaptured in the area of initial capture are listed under column 0.*

	Number of pools and/or riffles distant from marking site						
Recaptures	0	1	2	3	4	5	6
E. nigrum							
Observed	299	2	7	1	0	0	
Expected	127.59	1.82	150.54	1.00	13.88	0.19	
$X^2 = 381.24$, df = 5, $P < 0.001$							
E. flabellare							
Observed	114	2	11	0	3	0	1
Expected	36.18	0.84	35.01	0.35	28.25	0.65	29.54
$X^2 = 236.63$, df = 6, $P < 0.001$							

during non-reproductive periods. Scalet (1973) suggested that the orangebelly darter (*E. radiosum cyanorum*) may show more movement in the fall or winter than in summer, but no reasons for this were given.

Several authors have hypothesized that population pressure may be the factor which regulates fish movements (Funk 1957, Jenkins 1969, Flick and Webster 1975). Funk (1957) proposed that population pressure causes populations of stream fish to form sedentary and mobile groups. Nomadic or mobile individuals represent the annual overproduction in the population, and may colonize open territories. This type of dispersal is common in small mammal populations (Krebs et al. 1973, Butler 1980), and may also be important in regulating the numbers of fish in certain habitats.

TABLE 3

Schnabel population estimates and densities of johnny (E. nigrum) *and fantail* (E. flabellare) *darters for each pool (P) and riffle (R) in the study area, Harker's Run, Ohio.*

Species	Site	Schnabel Estimate	Density (fish/m^2)
E. nigrum	P1	180	1.26
	P2	136	0.53
	P3	100	0.95
E. flabellare	R1	280	12.17
	R2	124	1.88
	R3	74	5.29
	R4	205	20.50

Some darters may remain territorial during non-reproductive periods and defend particular areas against intruders (Winn 1958). The majority of movements displayed by johnny darters in Harker's Run were from the pool with the highest population density to the pool with the lowest population density. However, the majority of fantail darter movements were into the area with the highest density of the species. These results indicate that density may not be the only factor that influences the seasonal movements of stream fishes. Factors such as habitat quality, the types and quantities of food and cover available in an area, and the presence or absence of predators may also determine the number of fish that a section of stream can support. Habitat quality may differ among stream segments, and this in turn could affect the number of fish that use each area.

Fraser and Sise (1980) have shown that minnows in streams initially colonize the most suitable habitats available, and it is not until population density rises to a point where further immigration would lower the overall suitability of the original habitats to that of less favorable areas that these latter areas are colonized. In an equilibrium situation this would result in all available habitats being occupied, and those areas with high quality having higher population densities than areas with poorer quality. However, it is doubful that an equilibrium is maintained for any length of time in a stream ecosystem. Stream conditions are changing continuously, and death and recruitment modify the size of the fish population. Movements of fish from one area to another result when one habitat becomes temporarily overcrowded. Depending on the quality of the habitat involved, this can occur at high or low densities. Therefore, it is possible that a habitat with high population density (R4) may accommodate additional fish because of its high quality, while an area of poorer quality may be overcrowded at a much lower density (R3). The size of territories defended by darters should then differ in relation to habitat quality, with small territories tolerated in habitats of high quality but not in areas of poorer quality.

More than 75% of darter movements in this study were in an upstream direction. Upstream movements of fishes during nonspawning periods have been noted by other investigators (Hall 1972, Mendelson 1975), but previous studies of darters have revealed no general pattern in the movements of these fishes during the non-reproductive period (Reed 1968, Hall 1972, Scalet 1973). The reasons for the observed upstream movements in Harker's Run are unknown, but may have been correlated with foraging behavior, positive rheotaxis, and decrease in water temperature.

Distances of darter movement have not been well studied. Scalet (1973) recorded intra-raceway movements of less than 30 m for the orangebelly darter (*E. radiosum cyanorum*), but no inter-raceway movements were observed. Reed (1968) and Lee and Ashton (1981) observed movements of several darter species, but lengths of these movements were not reported (except for a single movement associated with flooding). Average distance travelled (60 m) by darters in this study was similar to the distance (54 m) between the centers of similar habitats (2 pools or 2 riffles) in Harker's Run. This suggests that most darter movements occurred between similar adjacent habitats. Hence, distance of movements was dependent upon the morphology of Harker's Run.

Published density estimates for several riffle-dwelling darter species range from 1.18–14.86 fish/m^2 (Wickliff 1940, Lachner et al. 1950, Schwartz 1965, Reed 1968, Scalet 1973). Values (1.88–20.50/m^2) for the fantail darter in Harker's Run were similar to these reported estimates. However, density values (0.53–1.26/m^2) for the pool-dwelling johnny darter were generally lower than values reported for riffle species. Smart and Gee (1979) noted that in pools autumn densities of the johnny darter are less than 5 fish/m^2. This value, though considerably higher than the Harker's Run estimates, was calculated from collections that were made in those pools where *E. nigrum* was most abundant.

In general, darter densities in pools were lower than densities in the riffles. This was not unexpected, as riffles support a greater abundance of food organisms per unit area than pools (Hynes 1970) and, hence, should accommodate more fish per unit area. This, combined with the paucity of other fish species in the riffles, may enable the darters to reach higher densities in these areas. Johnny darters often shared the pools in Harker's Run with schools of other fish species (e.g. *Ericymba buccata*, *Campostoma anomalum*), suggesting that its numbers may be regulated to some extent by interspecific competition for an already limited food resource.

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